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The nutritional composition and health benefits of New Zealand tamarillos

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A report prepared for
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Copy 7 of 7

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Contents

1 Executive summary

This report describes the results of nutritional and antioxidant analyses conducted on red and gold tamarillo for the New Zealand Tamarillo Growers Association. The key nutritional attributes of tamarillos are noted below. They:

- are low in fat and hence calories,
- are low in carbohydrate and the carbohydrate present is mainly in the form of fibre,
- are high in potassium but extremely low in sodium, which is a desirable balance for a healthy diet,
- contain other trace elements important for health, in particular copper and manganese,
- are a very good source of vitamin C, and
- make a significant contribution to the daily intake of vitamins A (equivalents from selected carotenoids), B_6 and E.

Of the antioxidant components represented, phenolics were present in the greatest amount in both red and gold tamarillos, followed by vitamin C. Carotenoids and vitamin E were present at the lowest levels. Red tamarillos had higher antioxidant activity than gold but both had higher antioxidant activity than many common foods.

2 Background

The tamarillo (*Cyphomandra betacea*) was formerly known as a 'tree tomato' because its flesh closely resembles that of a tomato. It is available in both red and yellow varieties, with the red being more popular and more common. It is an egg-shaped bright red fruit with yellow-orange flesh and black seeds that are surrounded by purple gelatin. The red colour is due to pigments called anthocyanins while the yellow-orange colour is due to carotenoids.

2.1 Composition of tamarillo

The New Zealand Food Composition Database contains some information on the standard nutritional composition of tamarillo (red and yellow) (Appendix I). Several components are of particular significance in terms of contribution to daily intake of nutrients. Based on this data, the levels of vitamins B_6, C and E present suggest that one tamarillo would give more than 5% of the RDI (recommended daily intake) of these nutrients. However, the vitamin E data is for a related record, rather than New Zealand data, so it may not be 100% reliable. For some of the nutrient elements (e.g. iron, magnesium and potassium) one or two tamarillos supply over 5% of the RDI.

In the USA, where nutrient claims and labelling requirements are very specific, tamarillos qualify for the following nutrient content claims:

- low in calories
- good source of fibre
- fat free (red) or low fat (gold)
- cholesterol-free
- sodium-free
- excellent source of vitamins C and E.

Although basic nutritional data exists, there is limited data on other components, e.g. phytochemicals, present in tamarillo. Dr Duke's phytochemical database lists some phytochemicals (e.g. anthocyanins: malvidin-3-diglucoside, malvidin-3-glucosyl-glucose, paeonidin-3-diglucoside, paeonidin-3-glucosyl-glucose, pelargonidin-3-diglucoside, pelargonidin-3-glucosyl-glucose; carotenoids: beta-carotene, beta-cryptoxanthin, lutein; Appendix II). However, this information is probably not comprehensive (or totally accurate), is not New Zealand-sourced and generally lacks quantitative substantiation.

2.2 Antioxidants

Antioxidants protect against the harmful effects of free radicals and other reactive oxidants. There are numerous diseases in which free radicals have been implicated, including the universal degenerative diseases of aging such as cancer, heart disease and cataracts, and diseases with more specific causes such as Parkinson's disease and pancreatitis. Vitamin C, vitamin E and β-carotene (provitamin A) have been regarded as the major nutritional antioxidants for many years. More recently other plant constituents, including other carotenoids and phenolics along with some flavonoids (e.g. quercetin, anthocyanins), have been shown to have significant antioxidant activity. Some of these classes of compounds may have other modes of action that are independent of antioxidant activity. Various classes of flavonoids have anticancer, antimutagenic, immune-stimulating, anti-allergic and antiviral effects. There is a lack of data on the antioxidant composition of tamarillos, although there are a few papers on their anthocyanin composition (anthocyanins are the red pigments). Amongst the major groups of antioxidants, tamarillo contains vitamins C and E, phenolics (including anthocyanins and other flavonoids) plus carotenoids. Various research groups have screened a variety of fruit for their antioxidant activity but none appear to have included tamarillo.

2.3 Project aim and work plan

The aim of this project was to gather information on the nutritional composition and antioxidants/phytochemicals present in tamarillos for the tamarillo industry. The intention was that this information would be examined for its potential use in promotional material.

The work was divided into two parts:

1. Antioxidant analyses
    - Antioxidant activity
    - Measurement of antioxidant components
        - total phenolics,
        - anthocyanins and other flavonoids,
        - total carotenoids, and
        - antioxidant vitamins – C and E.
2. Other nutritional data

    Based on existing data the recommendations were to measure:
    - Proximates:
        - moisture,
        - total nitrogen and from this protein,
        - total lipids,
        - ash,
        - carbohydrates: sugars and fibre,
    - Elements,
    - Vitamins: B_6 (note vitamins C and E are covered in part 1 above).

Analyses were conducted on both red and gold tamarillos and this report provides the data from these analyses.

3 Methods

3.1 Sample preparation

For each cultivar (red and gold) we took a pooled sample of 12 fruit to eliminate fruit to fruit variability. Fruit were placed in boiling water for approximately 1 minute and skins were removed. Fruit were then sliced longitudinally. Half of the fruit was pulped and frozen and the tamarillo 'puree' was held at -20°C until analyses could be performed. The remaining fruit were cut in half again (i.e. into quarters longitudinally), frozen and then freeze-dried.

Two separate batches of 12 tamarillos of each cultivar were processed. Duplicate analyses were then performed on each sample.

3.2 Standard nutritional analyses

The following analysis methods were used (these are standard methods for the New Zealand Food Composition Database). Note, these analyses were conducted on the frozen pulp.

- Proximates:
  - Moisture by oven drying (16 hours @ 103°C).
  - Total nitrogen by instrumental combustion method. Protein levels were determined by multiplication of total nitrogen levels by the standard conversion factor (6.25).
  - Fibre determination by AOAC Prosky method.
  - Sugars by gas chromatography.
  - Crude fat (lipids) by Soxhlet extraction.
  - Ash by ignition in furnace (6 hours @ 600°C).
- Elements by acid digestion followed by inductively coupled plasma emission spectrometry (ICP-ES).
- Vitamins by high performance liquid chromatography (HPLC).

Energy was expressed in units of kilojoules (kJ). All values were calculated from the energy-producing components in a food using conversion factors listed in Table 1 (as prescribed in the Australia New Zealand Food Standards code, volume 2, standard 1.2.8). Average energy content was also expressed as calories. The conversion factor is one calorie for each 4.18 kilojoules.

Table 1: Energy conversion factors.

Food component	Energy factor (kJ/g)
Carbohydrate (excluding unavailable carbohydrate)	17
Unavailable carbohydrate (including dietary fibre)	8
Fat	37
Protein	17

3.3 Quantification of antioxidants and antioxidant activity

3.3.1 Extraction of samples for measurement of total phenolics and antioxidant activity

Approximately 1 g of freeze-dried ground tamarillo was weighed out (in duplicate) and extracted with 10 ml 80% acetone for four hours in the dark at 10˚C. The extracts were then centrifuged at 10 000 g for 10 minutes before completing the analyses described below.

3.3.2 *Total phenolics*

Total phenolics were measured in the acetone extracts using Folin-Ciocalteu's reagent (Spanos & Wrolstad 1990). Gallic acid was used to prepare a standard curve and results were expressed in milligrams of gallic acid equivalents per 100 gram fresh weight (mg GAE/100 g FW). Total phenolic assays were carried out in duplicate on each sample.

3.3.3 *Antioxidant activity (ABTS) assay*

Antioxidant activity was measured using a modified ABTS assay (Miller & Rice-Evans 1996, 1997). The ABTS assay is an internationally recognised test. This is a measure of free radical scavenging ability of an extract in an aqueous system (although fat-soluble components, such as carotenoids, do perform moderately in this assay). Trolox (a water soluble vitamin E analogue) is used as a standard. We have a large database of activity levels for different dietary sources of antioxidants, which we will use for comparative purposes.

Duplicate assays were performed on each extract and at three different dilutions. The assay system is based on generating a free radical (which is coloured) and the ability of an extract to quench the radical and return it to a non-coloured "harmless" form. This method compares antioxidant activity of the extracts to Trolox, a water-soluble vitamin E analogue. Results are expressed as the amount of Trolox equivalent antioxidant capacity per hundred grams of fresh weight of material (μmol TEAC/g FW), which represents the amount of Trolox (vitamin E) that gives the same response as 100 g of kiwifruit.

3.3.4 *Total carotenoids*

Extraction was performed as above but with 100% acetone instead of 80%. Carotenoid levels were determined spectrophotometrically after partitioning into petroleum ether. For the basis of calculation the extinction coefficient used was that of ύ-carotene ($E^{1\%}_{1cm}$=2500).

3.3.5 *HPLC of anthocyanins and other phenolic compounds*

Extracts were centrifuged at 20 800 × *g* for 10 min before injecting directly on to a high-performance liquid chromatography (HPLC) column. The HPLC system comprised a solvent delivery system with an automatic sample injector and a variable wavelength UV detector (models W600, W717, and 996 PDA; Waters, Milford, MA). The RP-18 column (220 × 4.6 mm, Brownlee RP-18 Spheri-5, 5 μm C18; Perkin-Elmer Corporation, Norwalk, CT) was fitted with a guard column (15 × 3.2 mm, Aquapore RP-18; Applied Biosystems, Foster City, CA). Chromatographic traces were recorded using the Waters Empower software program scanning a wavelength from 250 to 700 nm. Samples (5 μl) were injected on to the column, which was maintained at 25°C, and eluted with a flow rate of 1.0 ml/min. Solvents were 10% (v/v) acetic acid in water (A) and acetonitrile (D). Initial solvent conditions were 100% A. A linear 48 min solvent gradient from 0 to 16% acetonitrile, and then a linear 2 min solvent gradient from 16 to 20% acetonitrile, then a linear 0.1 min solvent gradient from 20 to 50% acetonitrile with a 1.9 min hold at the final concentration were used. The column was returned to initial solvent composition over 0.5 min and re-equilibrated for 10 min before the next analysis. Eluted components were monitored at 280 nm for proanthocyanidins and phenols, 313 nm for phenolic acids, 350 nm for flavonols and 530 nm for anthocyanins.

4 Results and discussion

4.1 Nutritional composition

4.1.1 Proximates

Details of the proximate composition of tamarillos are given in Table 2, with more detail of the sugar composition in Table 3. Most of the components are in a similar range to those reported in previous work. Tamarillos are low in fat and hence calories and low in carbohydrate. The carbohydrate present is in a form of fibre.

Table 2: Proximate composition of tamarillos, edible portion (per 100 g FW).

		Amount for current study		Comparative data[a]	
Component	Units	Red	Gold	Red	Gold
Moisture	g	87.8	89.0	86.1	86.3
Energy	kcal	36	34	31[b]	27[b]
Energy	KJ	151	143	130[b]	112[b]
Nitrogen	g	0.29	0.31	0.32	0.31
Protein	g	1.8	1.9	2.0	1.9
Total fat (lipids)	g	0.5	0.2	0.36	0.48
Dietary fibre	g	3.6	3.1	3.3	3.3
Available carbohydrate (sugars plus starch[c])	g	4.3	4.6	3.8	3.7
Ash	g	1.5	1.1	0.82	0.78

[a] New Zealand Food Composition Database (Athar et al. 2003).
[b] Older calculation method used.
[c] Starch not measured but value of 0.3 taken.

Table 3: Sugar composition of tamarillos (g per 100 g FW).

Component	Amount for current study		Comparative data[a]	
	Red	Gold	Red	Gold
Fructose	1.3	1.5	1.0	0.9
Glucose	1.1	1.1	0.9	0.8
Lactose	0	0	0	0
Maltose	0	0	0	0
Sucrose	1.6	1.7	1.8	1.7

[a] New Zealand Food Composition Database (Athar et al. 2003).

4.1.2 *Elements*

Results for the elemental composition of the tamarillos are given in Table 4 (note some values are reported in mg and some in µg). Tamarillos are high in potassium but are extremely low in sodium, which is a desirable balance for a healthy diet. The copper level was higher than reported previously, perhaps due to the growing location or horticultural practices. Other elemental levels were similar to those reported previously.

Table 4: Elemental composition of tamarillos (per 100 g FW).

Element	Units	Results for current study		Comparative data[a]	
		Red	Gold	Red	Gold
Boron	mg	0.14	0.14	-[b]	-
Calcium	mg	14.5	9.5	10.7	10.6
Copper	mg	0.12	0.12	0.051	0.062
Iron	mg	0.32	0.41	0.57	0.44
Magnesium	mg	24	23	20.6	20.4
Phosphorus	mg	35	32	38.9	40.2
Potassium	mg	495	450	321	292
Sodium	mg	<0.6	<0.6	1.44	1.36
Zinc	mg	0.17	0.16	0.15	0.17
Aluminum	µg	<100	<100	-	-
Antimony	µg	<1	<1	-	-
Arsenic	µg	<7	<7	-	-
Barium	µg	27	30	-	-
Beryllium	µg	<2	<2	-	-
Bismuth	µg	<1	<1	-	-
Cadmium	µg	0.4	0.3	-	-
Caesium	µg	<0.5	<0.5	-	-

Element	Units	Results for current study		Comparative data[a]	
		Red	Gold	Red	Gold
Chromium	µg	<25	<25	-	-
Cobalt	µg	1.3	1.4	-	-
Lead	µg	<1	<1	-	-
Lithium	µg	<1	<1	-	-
Manganese	µg	185	240	114	185
Mercury	µg	<1	<1	-	-
Molybdenum	µg	1.2	<1	-	-
Nickel	µg	<25	<25	-	-
Rubidium	µg	270	170	-	-
Selenium	µg	<10	<10	0.1	0.1
Silver	µg	<5	<5	-	-
Strontium	µg	38	38	-	-
Thallium	µg	<1	<1	-	-
Tin	µg	<3	<3	-	-
Uranium	µg	<0.5	<0.5	-	-
Vanadium	µg	<25	<25	-	-

[a] NZ Food Composition Database (Athar et al. 2003).
[b] – indicates no data given.

In relation to the recommended daily intake of elements, tamarillos can contribute to intakes of potassium, copper and manganese (Table 5). Potassium is found in body fluids and is essential for the proper functioning of cells, including nerves. It is important in preventing high blood pressure. The body needs copper to be able to use iron properly (so having a tamarillo sauce or chutney with a steak may be a good idea). Manganese, like many other elements, is an important part of enzymes (particularly those involved in amino acid, cholesterol and carbohydrate metabolism) and it is also involved in the formation of bone.

Table 5: Typical daily requirements of key elements and the potential contribution of tamarillos.

Element	RDI[a] for adults	Suggested safe upper level of intake	% RDI from single serve of tamarillo[b]	
			Red	Gold
Calcium	1000-1200 mg	2500 mg	0.8	0.5
Chromium	20-45 µg	Not determined	ns[c]	ns
Copper	0.9-1.3 mg	10 mg	6.5	6.5
Iron	8-27 mg	45 mg	1.1	1.4
Magnesium	310-420 mg	Not determined	3.9	3.8
Manganese	1.8-2.6 mg	11 mg	5.0	6.5
Molybdenum	45-50 µg	2000 µg	1.5	ns
Phosphorus	700 mg	3000-4000 mg	3.0	2.8
Potassium	1950-5500 mg	No firm data but 10 g (10000 mg) in a single dose can be fatal	8.0	7.2
Selenium	55-85 µg	400 µg	ns	ns
Sodium	920-2300 mg	Not determined	ns	ns
Zinc	8-12 mg	40 mg	1.0	1.0

[a] RDI = recommended daily intake, average value (will vary depending on country recommendations age, sex, pregnancy, etc.).
[b] Based on a serving size of one tamarillo = 60 g (it should also be noted that this is based on raw tamarillos) and using average RDI.
[c] Not significant (<1%).

4.1.3 *Vitamins*

The levels of the selected vitamins measured (vitamins C, E and B_6) are given in Table 6. Of the vitamins represented, vitamin C was present in the highest amounts in both red and gold tamarillos, although it was higher in red fruit. Large ranges in vitamin C levels have been reported previously for tamarillos grown in New Zealand with the range for red being 19.3 to 41.6 mg/100 g and for yellow 24.6 to 33.2 mg/100 g (Dawes 1972). Vitamin C is the common name for ascorbic acid, the scurvy-preventing (anti-scorbutic) vitamin. Although many animals can synthesise vitamin C, humans cannot. Cigarette smoking depletes vitamin C. Vitamin C has a large diversity of functions including antioxidant and involvement in the production of collagen (the ‘cement’ that helps with the structure of muscles, vascular tissues, bones and cartilage). It also contribes to healthy teeth and gums, aids wound healing; fights infection, and is necessary for iron absorption (another reason for having a tamarillo sauce or chutney with a steak – as long as vitamin C is still present after processing). Fruits and vegetables, and their juices, are the main source of vitamin C in the diet.

Table 6: Vitamin composition of tamarillos (per 100 g FW).

Vitamin	Units	Result for current study		Comparative data[a]	
		Red	Gold	Red	Gold
C (ascorbic acid)	mg	34.3	24.7	29.8	31.0
B_6 (total)	mg	0.58	0.52	0.20	0.38
E (tocopherols)	mg	1.8	3.5	2.1	2.1

[a] New Zealand Food Composition Database (Athar et al. 2003).

The levels of vitamin B_6 reported in these samples were higher than has been reported previously in New Zealand (Athar et al. 2003). Vitamin B_6 (pyridoxine) plays a role in the synthesis of antibodies by the immune system, which are needed to fight many diseases. It helps maintain normal nerve function and also acts in the formation of red blood cells. Vitamin B_6 is also required for the chemical reactions needed to digest proteins; the higher the protein intake, the greater the need for vitamin B_6. This vitamin is present in a wide range of unprocessed foods (Truswell & Milne 2002), but major food sources are generally meats (0.1-0.5 mg/100 g), whole grain products (~0.3 mg/100 g), vegetables (0-0.3 mg/100 g) and nuts (0.1-0.9 mg/100 g).

The term vitamin E covers a group of fat-soluble compounds called tocopherols and tocotrienols. Alpha-tocopherol is the most common and biologically active. Its main functions are as an important antioxidant that may reduce the risk of some types of cancers and heart disease. It also provides dietary support for healthy heart, lung, prostate and digestive tract function. The main dietary sources of vitamin E are vegetable oils (e.g. corn, peanut, safflower, soya, sunflower, etc.) and wheat germ. Nuts, seeds, green leafy vegetables and whole grains contain smaller amounts.

Table 7 shows the contribution of tamarillos in relation to the recommended daily intake of vitamins. Tamarillos make a significant contribution to the daily intake of four vitamins: vitamins A (equivalents from selected carotenoids), B_6, C and E.

Table 7: Typical daily requirements of vitamins elements and the potential contribution of tamarillos.

Vitamin	RDI[a] for adults	Suggested safe upper level of intake	% RDI from single serve of tamarillo[b]	
			Red	Gold
Biotin	30-35 µg	Not determined	ns[c,d]	ns[c]
Folate	400-600 µg	1000 µg	ns[c]	ns[c]
Niacin	14-18 mg	35 mg	ns[c]	1.6%[c]
Pantothenic acid	5-7 mg	Not determined	ns[c]	ns[c]
Riboflavin	1.1-1.6 mg	Not determined	ns[c]	ns[c]
Thiamin	1.1-1.4 mg	Not determined	1.9%[c]	4.5%[c]
Vitamin A	700-1,300 µg	3000 µg	13.15%[c,e]	13.62%[c,e]
Vitamin B_6	1.3-2.0 mg	100 mg	21.09%	18.91%
Vitamin B_{12}	2.4-2.8 µg	Not determined	ns[c]	ns[c]
Vitamin C	30-120 mg	2000 mg	27.44%	19.76%
Vitamin D	5-15 µg	50 µg	ns[c]	ns[c]
Vitamin E	15-19 mg	1000 mg	6.35%	12.35%

[a] RDI = recommended daily intake, average value (will vary depending on country recommendations age, sex, pregnancy, etc.).
[b] Based on a serving size of one tamarillo = 60 g (it should also be noted that this is based on raw tamarillos) and using average RDI.
[c] Calculated from data from the New Zealand Food Composition Database (Athar et al. 2003).
[d] Not significant (<1%).
[e] Based on total vitamin A equivalents from beta-carotene (carotenoids).

4.2 Antioxidant composition and activity

4.2.1 Levels of key antioxidant components

The levels of antioxidant components for the red and gold tamarillo samples analysed are given in Table 8. Of the antioxidant components, phenolics were present in the greatest amount in both red and gold tamarillo, followed by vitamin C. Carotenoids and vitamin E were present at the lowest level.

Table 8: Antioxidant composition of tamarillos (average of duplicate extracts and analyses).

Sample	Total phenolics (mg GAE/100 g FW)	Total carotenoids (mg/100 g FW)	Vitamin C (mg/100 g FW)	Vitamin E (mg/100 g FW)
Red	190.8	1.71	34.3	1.8
Gold	116.6	1.77	24.7	3.5

4.2.2 *Phenolic composition*

Appendix III shows the typical HPLC traces at four different wavelengths for both a red and a yellow tamarillo sample. Of the phenolics, anthocyanins were present in the highest amounts followed by phenolic acids, with only small amounts of falavonols (Table 9).

The height of the peak at the different wavelengths can be used to provide some idea of the identity of the compound (note that the scale is slightly different at the different wavelengths). The main things of note were:

- In the red tamarillo there was one main anthocyanin with two others present in very small amounts (anthocyanins are the only compounds with peaks at 530 nm). More detailed analysis of the main peak spectrum indicated that it was delphinidin-3-rutinoside and the two smaller peaks were likely to be cyanidin-3-rutinoside and a pelargonidin glycoside (probably rutinoside). This agrees with the literature findings for the flesh (Wrolstad & Heatherbell 1974). Slightly different anthocyanins are present in the skin (cyanidin-3-rutinoside is the main component; Wrolstad & Heatherbell 1974) but we did not analyse this as it is not normally eaten. As expected from its lack of red colour, there were no anthocyanins present in gold tamarillo (i.e. no peaks present at 530 nm).
- Phenolic acids were present in significant amounts (these have the highest peak at 313 nm), as they are in many fruit. Conclusive identification of these was not made but one is probably chlorogenic acid. Wrolstad & Heatherbell (1974) also reported that chlorogenic acid was present in the flesh (and at even higher levels in the skins) but they did not report on any other phenolic acids. There are no other reports in the literature of the phenolic acid composition of tamarillo. The red and gold tamarillos had a similar composition, although the gold appeared to have a slightly higher number of compounds but in lower quantities (Table 9).
- There were small quantities of flavonols (highest peak at 350 nm), with two main components. More detailed analysis of the peak spectra indicated that they were possibly kaempferol glycosides. Wrolstad & Heatherbell (1974) also noted that flavonols were present but did not identify them. The same two flavonols were present in the red and gold tamarillos but at much lower amounts in the gold (Table 9).

Based on the levels of total phenolics, there may be other compounds present that we did not quantify from the HPLC. Proanthocyanidins are probably present, and have strong antioxidant activity.

Table 9: More detailed phenolic composition of tamarillos (average of duplicate extracts and analyses).

Sample	Anthocyanins (mg GAE/100 g FW)	Flavonols (mg/100 g FW)	Phenolic acids (mg/100 g FW)
Red	82.4	6.4	29.6
Gold	0.0	2.5	18.8

4.2.3 Antioxidant activity

The red tamarillos had higher antioxidant activity than the gold (Table 10). This would be expected since the gold were lower in total phenolics and did not contain anthocyanins, which are strong antioxidants.

Table 10: Antioxidant activity of tamarillos (average of duplicate extracts and analyses).

Sample	Antioxidant activity (µmole TEAC/100 g FW)
Red	1659.4
Gold	1002.3

4.2.4 Comparison with other fruit and dietary sources of antioxidants

Tamarillos rate very well as a source of dietary antioxidants compared to other common fruits and vegetables. They do not contain as much vitamin C as berry fruit or citrus but rate much higher than other more commonly eaten fruit, such as apples and bananas (Table 11). Their levels of phenolics are not as high as many other fruit (Table 12) but they are higher in antioxidant activity than many (Table 13). This indicates that the phenolics (or other compounds) present are stronger antioxidants. Tamarillos rank very highly as a source of antioxidants compared with other foods (Table 14).

Table 11: Vitamin C content of some common fruit.

Fruit	Vitamin C (mg/100 g FW)[a]
Apple	8
Apricot	7
Banana	10
Blackcurrant	160
Blueberry	10
Cherry	20
Grape	4
Kiwifruit	93
Orange	50
Pear	3
Pineapple	25
Plum	3
Raspberry	14
Strawberry	46
Tamarillo - red	**34.3**
- gold	**24.7**
Watermelon	5

[a] Data from New Zealand Food Composition Database (Athar et al. 2003).

Table 12: Total anthocyanin and phenolics levels in some fruit (data compiled from various sources).

	Total anthocyanins (mg/100 g FW)	Total phenolics (mg/100 g FW)
Apples	0-	187
Apricot	0	66
Banana	0	120
Blackcurrants	250-750 (571)	1057-1291
Blueberries	25-503 (336)	372-997
Boysenberries	160-430 (300)	479-803
Cherry	90	178
Grape	8-403	900-950
Orange	0	39
Pineapple	0	45
Raspberries	20-220	300
Strawberries	28-70	240
Tamarillo - red	82	**191**
- gold	**0**	**117**
Watermelon	0	12

Table 13: Antioxidant activity of some common fruit.

Fruit	Antioxidant activity (μmol TEAC[a] /100 g FW)
Apple (red-skinned)	500[b], 159[c]
Apricot	144[c]
Banana	64[c]
Blackcurrant	12,800[b]
Blueberry	6,340[b], 743[c]
Cherry	1,450[b], 269[c]
Grape (black)	385[c]
Kiwifruit	800[b], 228[c]
Orange	874[c]
Pear	219[c]
Pineapple	991[c]
Plum (red)	511[c]
Raspberry	1679[c]
Strawberry	1,850[b], 1,094[c]
Tamarillo - red	**1,659**
- gold	**1,002**
Watermelon	69[c]

[a] TEAC = Trolox equivalent antioxidant capacity, as measured by the ABTS assay.
[b] Lister (personal data).
[c] Pellegrini et al. (2003).

Table 14: Antioxidant activity (as measured by the ABTS assay) of some foods and supplements on a per 100 g basis and per standard serving.

Dietary source		Antioxidant activity μmol TEAC/100 g[a]	Antioxidant activity μmol TEAC/serve
Berryfruit	Blackcurrants	19300	7600
	Blueberries	7750	5200
	Boysenberries	9270	4850
	Strawberries	2089	1650
Bread	White	115	30
	Wholemeal	198	55
	Mixed grain	250	70
Cereals	Barley	2653	-
	Maize	694	-
	Oats	275	-
	Rye	826	-
	Wheat	442	-
Supplements	Selenium ACE	900	900
	ACE	855	855
	Antioxidant mix 1	1183	1183
	Antioxidant mix 2	27	27
	Pine bark	189	189
	Conc. fruit extract	436	872
	Conc. vege extract	75	150
Vegetables	Broccoli	249	230
	Carrot	198	130
	Cauliflower	106	95
	Lettuce, heart	77	45
	Lettuce, red leaf	986	355
	Onion	273	170
	Potato	109	185
	Tomato	84	140

[a] Apart from the supplements for which the activities are expressed per capsule.

5 Acknowledgements

Thank you to Lesley Hedges for preparing the samples.

6 References

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Appendices

Appendix I Standard nutritional composition of red and gold tamarillos, from the NZ Food Composition Database (Athar et al. 2003)

Tamarillo, red, flesh and seeds, fresh

	Amount in 100 g edible portion		
	Units	Mean	Std error
PROXIMATES			
Water	g	86.08	0.24
Energy	kcal	31	-
Energy	kJ	130	-
Protein (Nitrogen x 6.25)	g	1.99	0.05
Total fat	g	0.36	-
Carbohydrate, available	g	3.8	-
Dietary fibre (Englyst 1988)	g	3.3	-
Ash	g	0.82	0.03
ELEMENTS			
Sodium	mg	1.44	0.19
Magnesium	mg	20.6	0.7
Phosphorus	mg	38.9	2.1
Sulphur	mg	17.2	-
Chloride	mg	29.8	-
Potassium	mg	321	13
Calcium	mg	10.7	0.5
Manganese	µg	114	-
Iron	mg	0.57	0.03
Copper	mg	0.051	-
Zinc	mg	0.15	-
Selenium	µg	0.1	-
VITAMINS			
Retinol	µg	0	-
Beta-carotene equivalents	µg	1135	-
Total vitamin A equivalents	µg	189.167	-

	Amount in 100 g edible portion		
	Units	Mean	Std error
Thiamin	mg	0.043	-
Riboflavin	mg	0.024	-
Niacin	mg	0.271	-
Potential niacin from tryptophan	mg	0.3	-
Vitamin B_6	mg	0.198	-
Pantothenate	mg	0.04	-
Biotin	µg	0.1	-
Folate, total	µg	4	-
Vitamin B_{12}	µg	0	-
Vitamin C	mg	29.8	1.9
Vitamin D	µg	0	-
Alpha-tocopherol	mg	1.94	-
Vitamin E	mg	2.09	-
FATTY ACIDS			
Total saturated fatty acids	g	0.049	-
Total monounsaturated fatty acids	g	0.055	-
Total polyunsaturated fatty acids	g	0.148	-
OTHER LIPIDS			
Cholesterol	mg	0	-
ADDITIONAL			
Acid,citric	g	1.835	-
Acid,malic	g	0.171	-
Alcohol	g	0	-
Alpha-carotene	µg	10	-
Beta-carotene	µg	600	-
Carbohydrate, available	g	3.8	-
Carbohydrate, total (by difference)	g	10.8	-
Cryptoxanthin	µg	1059	-
Density	kg/l	1.06	-
Dietary fibre	g	3.3	-
Dry matter	g	13.92	0.24
Fructose	g	0.95	-

	Amount in 100 g edible portion		
	Units	Mean	Std error
Glucose	g	0.85	-
Insoluble non-starch polysaccharides	g	2.8	-
Lactose	g	0	-
Lactose (monosacc)	g	0	-
Maltose	g	0	-
Maltose (monosacc)	g	0	-
Pectin	g	0.85	0.03
Soluble non-starch polysaccharides	g	0.5	-
Starch	g	0.32	-
Starch (monosacc)	g	0.36	-
Sucrose	g	1.71	-
Sucrose (monosacc)	g	1.80	-
Total available sugars	g	3.5	-
Total available sugars (monosacc)	g	3.60	0.19
Total dietary fibre (Prosky, 1984)	g	3.3	-
Total niacin equivalents	mg	0.6	-
Total nitrogen	g	0.32	0.01
Carbohydrate exchange		0.38	-

Common Measure: 1 tamarillo, 60 g.

***Tamarillo, yellow**, flesh and seeds, fresh.*

	Amount in 100 g edible portion		
	Units	Mean	Std error
PROXIMATES			
Water	G	86.30	0.63
Energy	Kcal	27	-
Energy	kJ	112	-
Protein (Nitrogen x 6.25)	G	1.95	0.09
Total fat	G	0.48	-
Carbohydrate, available	G	3.7	-
Dietary fibre (Englyst, 1988)	G	3.3	-
Ash	G	0.78	0.06
NUTRIENT ELEMENTS			
Sodium	Mg	1.36	0.38
Magnesium	Mg	20.4	1.0
Phosphorus	Mg	40.2	3.8
Sulphur	Mg	18.9	-
Chloride	Mg	13.0	-
Potassium	Mg	292	40
Calcium	Mg	10.6	2.0
Manganese	g	185	-
Iron	Mg	0.44	0.04
Copper	Mg	0.062	-
Zinc	Mg	0.17	-
Selenium	g	0.1	-
VITAMINS			
Retinol	g	0	-
Beta-carotene equivalents	g	763	-
Total vitamin A equivalents	g	127	-
Thiamin	Mg	0.093	-
Riboflavin	Mg	0.009	-
Niacin	Mg	0.567	-
Potential niacin from tryptophan	Mg	0.3	-
Vitamin B_6	Mg	0.378	-
Pantothenate	Mg	0.04	-
Biotin	g	0.1	-
Folate, total	g	4	-
Vitamin B_{12}	g	0	-

	Amount in 100 g edible portion		
	Units	Mean	Std error
Vitamin C	mg	31.0	2.7
Vitamin D	µg	0	-
Alpha-tocopherol	mg	1.90	-
Vitamin E	mg	2.05	-
FATTY ACIDS			
Total saturated fatty acids	g	0.066	-
Total monounsaturated fatty acids	g	0.073	-
Total polyunsaturated fatty acids	g	0.197	-
OTHER LIPIDS			
Cholesterol	mg	0	-
ADDITIONAL INFORMATION			
Alcohol	g	0	-
Available non-reducing sugars	g	0.29	0.05
Available reducing sugars	g	3.17	0.16
Beta-carotene	µg	763	-
Carbohydrate, available	g	3.7	-
Carbohydrate, total (by difference)	g	10.5	-
Density	kg/l	1.06	-
Dietary fibre	g	3.2	-
Dry matter	g	13.70	0.63
Fructose	g	0.91	-
Glucose	g	0.82	-
Insoluble non-starch polysaccharides	g	2.8	-
Lactose	g	0	-
Lactose (monosacc)	g	0	-
Maltose	g	0	-
Maltose (monosacc)	g	0	-
Pectin	g	1.13	0.18
Soluble non-starch polysaccharides	g	0.5	-
Starch	g	0.28	-
Starch (monosacc)	g	0.31	-
Sucrose	g	1.65	-
Sucrose (monosacc)	g	1.73	-
Total available sugars	g	3.4	-
Total available sugars (monosacc)	g	3.46	0.23
Total dietary fibre (Prosky, 1984)	g	3.2	-
Total niacin equivalents	mg	0.9	-

	Amount in 100 g edible portion		
	Units	Mean	Std error
Total nitrogen	g	0.31	0.01
Carbohydrate exchange		0.37	-

Appendix II

Data on the phytochemical composition of tamarillo from given in Dr Duke's Phytochemical and Ethnobotanical Databases (2004)

Chemical	Part of plant	Lo (ppm)	Hi (ppm)
Anthocyanins	Fruit	-[a]	-
Ascorbic acid	Fruit	223	2060
Ash	Fruit	6100	71000
Beta-carotene	Fruit	3	32
Beta-cryptoxanthin	Fruit	-	-
Calcium	Fruit	39	5780
Carbohydrates	Fruit	103000	838000
Fat	Fruit	600	64000
Fiber	Fruit	14000	243000
Fructose	Fruit	-	-
Iron	Fruit	6	57
Kilocalories	Fruit	3290	3550
Lutein	Fruit	-	-
Maltose	Fruit	-	-
Malvidin-3-diglucoside	Plant	-	-
Malvidin-3-glucosyl-glucose	Fruit	-	-
Niacin	Fruit	10	85
Nitrogen	Fruit	2230	4450
Paeonidin-3-diglucoside	Plant	-	-
Paeonidin-3-glucosyl-glucose	Fruit	-	-
Pectin	Fruit	-	-
Pelargonidin-3-diglucoside	Plant	-	-
Pelargonidin-3-glucosyl-glucose	Fruit	-	-
Phosphorus	Fruit	130	3400
Protein	Fruit	15000	156000
Riboflavin	Fruit	0.3	3
Solacarpoine	Plant	-	-
Starch	Fruit	10000	140000
Sucrose	Fruit	-	-
Sugars	Fruit	50000	375000
Thiamin	Fruit	0.3	7
Water	Fruit	827000	87800
Zeaxanthin	Fruit	-	-

[a] No quantitative data, only reported as present.

Appendix III

HPLC traces of red and gold tamarillos:

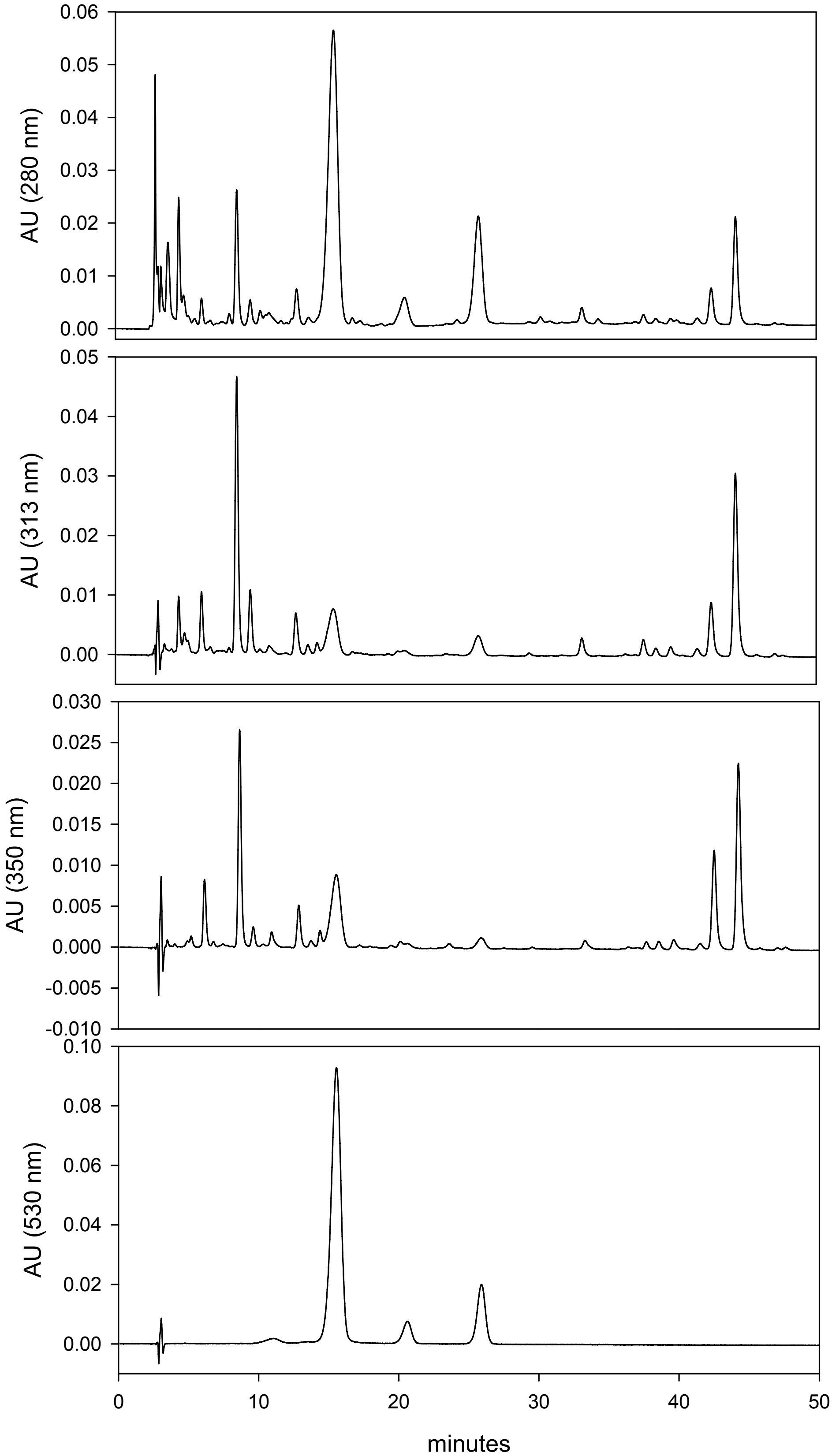
280 nm = general phenolics

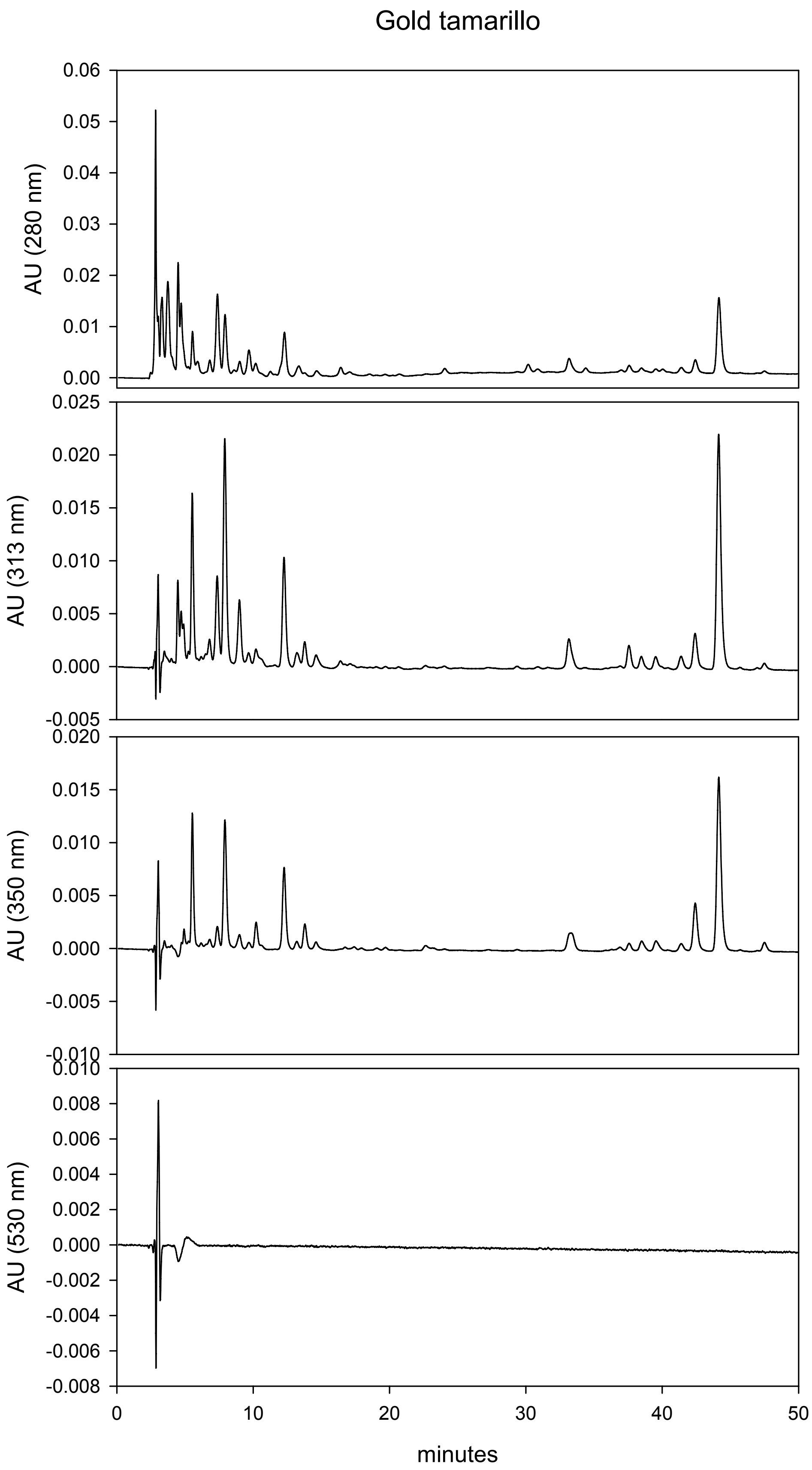
313 nm = phenolic acids

350 nm = flavonols

530 nm = anthocyanins

Red tamarillo





Gold tamarillo
AU (280 nm)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
AU (313 nm)
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
AU (350 nm)
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
AU (530 nm)
0.010
0.008
0.006
0.004
0.002
0.000
-0.002
-0.004
-0.006
-0.008
0
10
20
30
40
50
minutes